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ADAPTIVE SPHERICAL FORWARDING WEDGE USING DECENTRALIZED GEOGRAPHIC ROUTING IN WSN

Dr. P. Sengottuvelan [1] | P. Sathya [2]

[1] Associate Professor, Department of Computer Science, Periyar University PG Extension Centre, Dharmapuri - 636705, India.
[2] Research scholar, Department of Computer Science, Periyar University PG Extension Centre, Dharmapuri - 636705, India.

ABSTRACT

One of the most significant concerns in the maneuver of Wireless Sensor Network (WSN) is the real-time data delivery. This paper addresses the crisis of real-time data delivery and void node problem in three dimensional WSN, which has a significant impact on the network performance. In order to provide a precise route calculation for reliable data delivery the third coordinate of the location sensor nodes is considered in this article. Additionally, two different heuristic solutions for void node problem in three dimensional spaces have been provided to lift up the effect of long route and spares regions on assurance of real-time data delivery. In order to afford a wide applicable soft real-time routing protocol two decentralized geographical routings are proposed: Three Dimensional Real-Time Geographical Routing Protocol (3DRTGP) and Energy-Aware Real-Time Routing Protocol for Wireless Sensor Networks (EART). 3DRTGP and EART are deliberate to fit with WSNs that are deployed in 3D space. Both protocols promote from utilizing the third coordinate of nodes' locations to achieve less packet end to end (E2E) delay and packet miss ratio. In 3DRTGP, void node problem in 3D space was solved based on adaptive packet forwarding (PFR) region. 3D-VNP solution solely was done locally and without any messaging overhead.

KEY WORDS: 3DRTGP, EART, PFR, SFW, E2E.

I. INTRODUCTION

An impressive development of micro-sensor technology has enabled small and smart devices to provide new application opportunities with low power and low cost hard- ware. These smart devices are called sensor nodes which are equipped with different kinds of sensing, processing, storage, power source and wireless communication units. Many physical phenomena can be pragmatic and monitored by deploying a huge number of sensor nodes. These sensors can network wirelessly and accumulate data cooperatively about a physical environment and then route it to the base station (BS). BS is a more prevailing node that has more processing, storage capacity, power source and acts as a gateway between sensor network and a special computer server.This set of connected sensor nodes is called wireless sensor network(WSN). WSNs can be employed by many applications which oblige hundreds or even thousands of sensor nodes in remote and inaccessible areas[1]. Current and future applications of WSNs entail real-time data gathering and delivery such as in smart grid monitoring, disaster control and operation, military applications, object tracking, environment monitoring, health care, home automation, industrial monitoring and surveillance[11]. Routing data from the nodes to BS, in WSNs, is a challenging task due to infrastructure-less communications and frequent topology changes. The main weaknesses of the WSNs are the limitations associated with storage capacity, bandwidth, power resources and communication range[2]. This Section discusses examples of few WSN applications, challenges in WSNs, problem statement, and contributions.

II. RELATED WORK

The research work in this paper is related to the real-time data delivery in 3D-WSNs and 3D-VNP. The related work throughout this paper focuses on real-time algorithms and energy aware real-time algorithms with VNP solution[3].

The contribution of this sector is twofold. First, the 3D real-time geographical routing protocol (3DRTGP) is proposed for 3D deployed WSNs, which provides a soft real-time capability. The real-time operation is achieved by the protocol using an adaptive conical packet forwarding region (PFR) and selecting fast forwarding nodes in the PFR. The PFR limits the number of forwarding nodes in the direction of the destination, which reduces channel contention and congestion caused by unnecessary forwarding. Adjusting the forwarding probability of the nodes based on their queue length improves the delay experienced by packets and allows the protocol to provide delay guarantees. Second, an effective heuristic solution for the VNP in 3D WSNs is provided. This solution allows the proposed protocol to have a reliable operation in the event of having void regions. Functionality of the proposed protocol was demonstrated by extensive simulation studies and network performance was evaluated against the competing protocols[9]. Based on evaluations, the proposed protocol is a viable and reliable option for 3D geographical routing in WSNs for a number of time critical applications.

- Redundant transmission problem in GRPs: GRPs usually depend on one of the following techniques to forward the traffic from source/relay nodes to the destination:

A. Region Based Forwarding (RBF)

In this RBF technique, a geographical routing relies on forwarding a packet to a set of nodes that is located in the same region. This causes more packet forwarding than necessary, which leads to packet collisions, congestions and missed deadlines, eventually causing the protocols to not meet the real-time requirements. For this reason, GRPs must have the ability to detect the congested region and dynamically change the forwarding region to avoid packet loss.

B. Greedy Forwarding Technique (GFT)

In this GFT technique, packets are forwarded from source to destination along the shortest straight path between source and destination nodes. The nodes that are located on this path will be overused and depleted of their energy which causes traffic Congestion and generates VNP. Both congestion and VNP lead to delay in packet delivery and most of them miss their required deadlines. For this reason, it is important to make a routing protocol with the property of congestion detection to avoid packet delay and VNP generation [4].

I). **Node's energy:** Discarding the energy of the nodes in the forwarding decision may result in selecting nodes with low available energy which causes a rapid network partitioning. Therefore, an energy aware property must be integrated in the forwarding decision to enhance the protocol's reliability and efficiency.

In this paper, two novel distributed soft real-time GRPs are proposed:

1) Three dimensional real-time geographical routing protocol(3DRTGP): This protocol is designed to achieve real-time data delivery in WSN deployed in 3Dspace[5].

2) Energy aware three dimensional real-time geographical routing protocol(EART): This protocol is an enhanced version of 3DRTGP designed to achieve soft real-time data delivery with energy aware property in WSN deployed in 3D space.

III. ENERGY-AWARE REAL-TIME ROUTING PROTOCOL FOR WIRELESS SENSOR NETWORKS

Energy aware and real-time communications are critical issues in WSNs. This is because wireless sensors have limitations in terms of power supply, memory, and processing ability. Real-time communication is very important in many of WSNs applications. For example, in seismic monitoring and fire fighting applications appropriate actions must be made immediately as delay may cause devastating damage. In order to have such critical detected data to be delivered instantly and accurately, the energy in sensor nodes must be taken into account in routing decision[6]. Discarding the node's energy metric in real-time routing decision may cause repetitive selection of the same sensors. These repetitive selections leads to rapid network partition, generate void regions, and cause unreliable data delivery. Moreover, ignoring the delay metric in sensor node in routing decision may force the transmitted packets to take a longer detour to reach their destination, which violates the real-time requirements. For these reasons both metrics must be considered to meet the time sensitive requirements and delay network partitioning.

In literature, power aware and real-time routings rely on the global information of network [1,3]. This sort of topological routings is inefficient because sensor nodes have to periodically update their routing tables[8]. This periodical update increases the packet latency, network overhead and energy depletion. Fortunately, GRPs have low overhead as they do not require periodical route discovery or route maintenance. These characteristics make GRPs a good choice for designing a real-time protocol with power aware property. In this Section, the work in part 3 is extended to design a real-time and power-aware routing protocol[7]. This protocol is called: Energy-Aware Real- Time Routing Protocol for Wireless Sensor Networks (EART). This protocol is designed to provide a data delivery guarantee with a minimum energy us- age based packet forwarding mechanism in form of spherical forwarding wedge (SFW). Therefore, the queuing delay in the potential forwarding node (PFN) and energy are an integrated in the protocol forwarding semantic. The main contributions of in this work are:

a. Ensuring real-time data delivery.
b. Extending network lifetime.
c. Solving VNP in 3D WSN in a novel way.
d. Minimizing the networks overhead.

IV. PERFORMANCE EVALUATION

A. Performance Analysis

A stationary WSN of, η, homogeneous sensor nodes deployed in three dimensional (3D) terrain of volume V is considered. It is assumed that every node can acquire its location information, (Nx, Ny, Nz), through an embedded GPS or any location service . At the deployment time all nodes are programmed to learn the destination's location, (Dx, Dy, Dz) and the network density, ρ. Nodes have the same, initial energy of E0 Joules and spherical transmission range of, Every node can act as source to sense and report events, or relay to forward the reports of other nodes to the destination. The energy-aware and real-time protocol (EART) is designed to meet the real-time requirements and ensures that the network can operate for a long time. This protocol consists of three phases:

1) The first phase is spherical forwarding wedge (SFW) mechanism.

2) The second phase is forwarding probabilistic mechanism.

3) The third phase is detecting and solving VNP in 3D WSNs (3D-VNP).

In SFW, a node forwards a packet based on a region based forwarding technique through a SFW. Then one of the nodes that are located in the SFW will be probabilistically selected to forward the packet to the next hop neighbor. The selected forwarding node will become a sender and attach its location information(Sx, Sy, Sz), to the transmitted packet so that the next hop nodes can identify if they are in SFW or not. In the probabilistic forwarding mechanism, three parameters are considered:

1. Intra-node queuing delay.
2. The residual energy in a potential forwarding node (PFN).
3. Expected residual energy in PFN's neighborhood.

The third phase deals with 3D-VNP where there is no node in the selected SFW, and tries to find another reliable route to deliver the packet to the destination.

B. Spherical Forwarding Wedge Mechanism

This phase is utilized to reduce the number of forwarding nodes in 3D space as it considers a small volume of transmission range, and provides an accurate route description by considering the third coordinate of the nodes. Reducing the number of forwarding node has a significant effect on minimizing the redundant transmission, which causes more energy depletion and increases packet miss ratio. Fig. 4.3 illustrates 2D projection of SFW and potential forwarding node (PFN) in this wedge.

The angle that bounds the spherical forwarding region , α, is solely dependent on the network density, ρ. Based on the angle of the wedge and destination's location every node can check if it is in SFW of the previous hop sender or not. Then, it evaluates its forwarding eligibility by testing the following condition,

$$\varphi = \mathrm{atan2}[\ (\overrightarrow{SN} \times \overrightarrow{SD}) \times (\overrightarrow{SD} \times \overrightarrow{SO}) \bullet \overrightarrow{SD},\ (\overset{2}{-}S\rightarrow A \times -S\rightarrow D) \times (-S\rightarrow D \times -S\rightarrow O)] \leq \alpha$$

"SD"

where, φ, represents the angle between the plane that is defined by the vectors

−S→D and −S→O and the plane that is defined by the vectors −S→N and −S→O.

Once the condition in (4.1) satisfied the node will calculate its forwarding probability (as stated in next subsection). Otherwise it will keep the packet for a packet round trip time (RTT) for further processing to deal with VNP once it occurs..

C. Spherical Forwarding Wedge Mechanism

The objective of the forwarding probabilistic mechanism phase is to reduce the number of forwarding nodes in SFW and to identify a PFN with better link's quality and low queuing delay. Hence, every node in SFW calculates its forwarding probability, q, to determine its forwarding eligibility. This probability depends on two factors:

Energy metric, PE, Delay metric, Pτ which includes queuing delay in PFN, τq and average estimated delay in its neighborhood, τav. The energy metric captures the energy in PFN, En, and the expected energy in its neighborhood, Es. The node calculates its delay metric only if it has available energy more than the average energy in neighborhood, Eav, which is equals to, Es. If that is not the case the node will drop the received packets where ηs is the number of neighboring nodes. The energy metric is given by,

$$P_E = \frac{E_n}{E_s},$$

The node can calculate the energy in its neighborhood as follows: the initial total energy in neighborhood is, Es = ηs×E0, then each time the node transmits a packet it deducts the receiving energy, Erx, from all its neighborhood, Es,

Es − ηs × Erx. Moreover, each time the sender hears a packet from one of the neighboring node the sender assumes that at least half of its neighbors will hear the packet and deducts the overhearing energy and one transmitting cost form,

2Es, that is Es − (ηs) × Erx − Etx,where Etx represents the transmission energy. The delay metric, Pτ , captures the packet's delay in the PFN in order to avoid the congested nodes, which is given by,

$$P_\tau = \boxminus 1 - \left(\frac{(\tau_{pr}+\tau_q+\tau_t)}{\tau_{av}}\right) \quad if \left(\frac{ND}{(\tau_{pr}+\tau_q+\tau_t)}\right) > \left(\frac{SD}{\tau_{av}}\right)$$

follows,
q = γ × Pτ + (1 − γ) ×PE)

The parameter, γ ∈ [0, 1] is used to balance between the delay metric (4.3) and the energy metric (4.2) in the forwarding decision. For smaller, γ, the protocol tends to choose a node with better energy, while large, γ, the protocol tends to the node with low E2E delay.

D. Void node problem detection and solution

3D-VNP is depicted is no node in the shaded wedge. The objective of this phase is to detect and recover from 3D-VNP once it occurs. This phase also can detect the congested regions and forward the packets to less congested areas. The sender senses VNP through overhearing of the transmitted packet. Thus, if the sender node does not overhear the transmitted packet it considers the selected SFW as void region or as congested region. Then, the sender retransmits the packet after RTT. All nodes located outside the first, SFW1, and located in wedge SFW2, which is bounded by dihedral angle α and 2 × α and wedge SFW3, which bounded by −α and −2α will consider the forwarding task. This process is shown in Fig.1. The process continues until the packet is forwarded successfully by one of the next hop neighbors.

V. RESULTS AND DISCUSSION

The evaluation of EART protocol has been conducted based on OMNeT++ with MIXIM framework. The simulation parameters are in Table 3.1 and many to one traffic pattern was used with a constant bit rate (CBR). The network with 1000 nodes were uniformly and randomly deployed in a three dimensional terrain of 500 × 500 × 200 m3 volume. The packets' deadline was set to 250milliseconds (ms). The performance of the protocol was evaluated based on four metrics. These metrics are: i). Energy consumption per packet, ii). Packet end-to-end (E2E) delay, iii). Packet miss ratio, and iv). Network lifetime.

Energy consumption per packet is the average consumed energy in all of sensors for every successfully delivered packet to the destination. E2E delay is the time spent by a packet to travel from the source node to the destination node. The packet miss ratio is defined as the ratio of the packets that miss their deadlines out of the total number of transmitted packets. The network lifetime is defined as the duration of time between the network deployment time until a partitioning occurs. These metrics have been used to evaluate the performance of EART against ABLAR[10] and 3DRTGP. Both ABLAR and 3DRTGP use a restricted forwarding region mechanism to limit the number of potential forwarding nodes. However, none of them are able to capture the energy consumption in the network.

A. Average Energy Consumption per Packet

In this set of experiments, the average energy consumption per packet in EART, ABLAR and 3DRTGP were compared in order to gain a clear perspective on the effect of integrating the energy and E2E in forwarding decision on the network performance. This good performance is due to considering the available energy in the potential forwarding node and its neighborhood. Although, the increase the traffic load causes more congestion and collision, EART could handle this problem by considering the delay metric in the forwarding decision. Hence, traffic

can be deviated to other areas with less traffic load. On the other hand, 3DRTGP does not consider the available energy in the sensors, and for this reason it consumes more energy than EART. ABLAR depends on the periodical neighbor exchanging messages, which incurs sensor nodes more energy than in other protocols.

VI. CONCLUSION

This paper proposed a detailed study of tuning parameters that can be set to make the protocol fit with time sensitive applications. The effect of discarding the third coordinate in sensor node locations is investigated through a set of experiments. These experiments support the necessity of considering the three dimensional coordinates for accurate routing calculation. The results show that ignoring third coordinate in routing calculation has significant impact on the network performance. Three test scenario of region based routing protocols, which are 2D-RGRP implemented in 2D-WSN, 2D-RGRP implemented in 3D- WSN, and 3D-RGRP implemented in 3D-WSN, are designed and their results compared with each other to verify the effect of location errors on the network performance.

The current versions of 3DRTGP and EART do not consider the mobility of sensor nodes in WSNs. However, a majority of mobile systems employ GPS devices, which can provide the location information of sensor nodes in real- time and the location of destination node can be pre-programmed in all sensors before the network is deployed in the targeted terrain. With these provisions, 3DRTGP and EART can be easily utilized by mobile networks, such as UAV networks. Mobile versions of the protocols will be investigated in future studies.

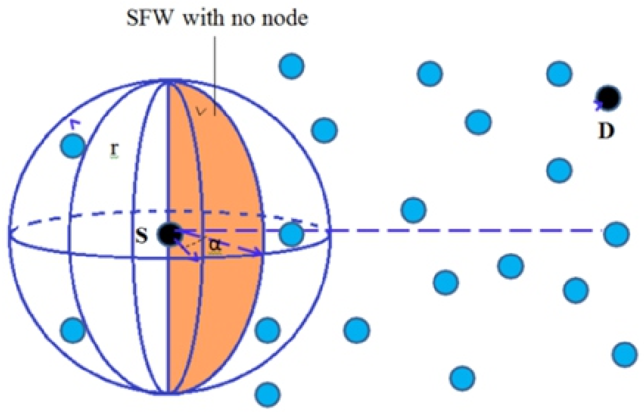

Fig.1. 3D shaded SFW with VNP

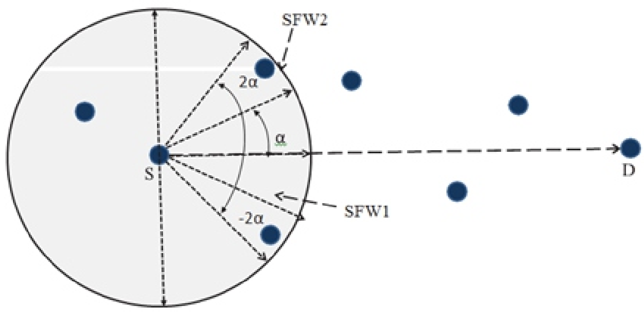

Fig.2. 2D projection of VNP solution in 3D WSNs

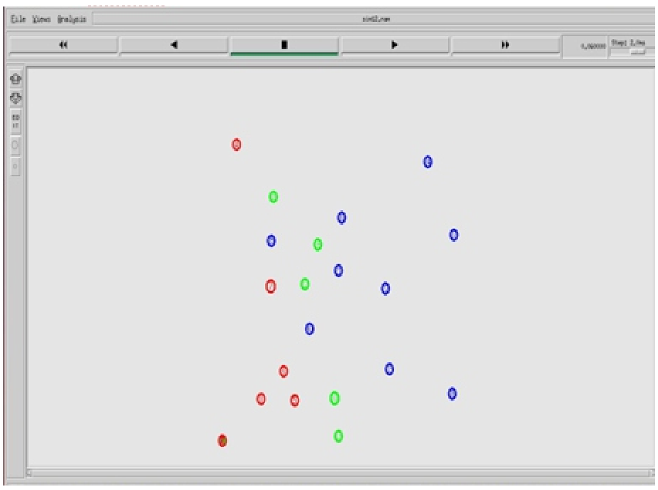

Fig.3. Network Creation and Node allocation

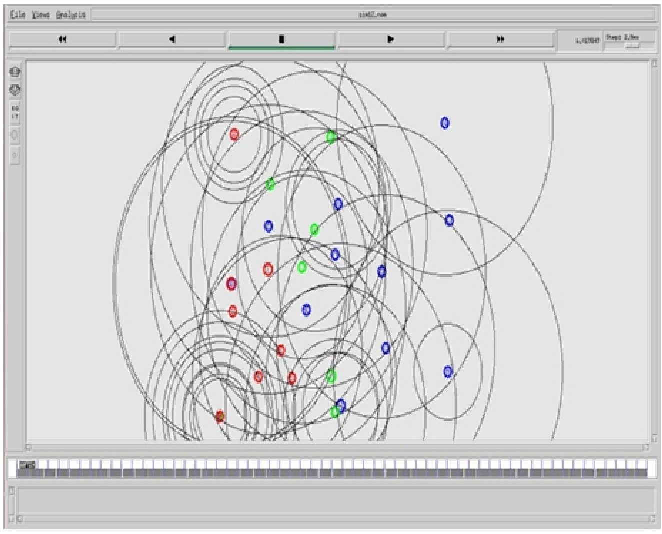

Fig.4. Coverage area notification for each node

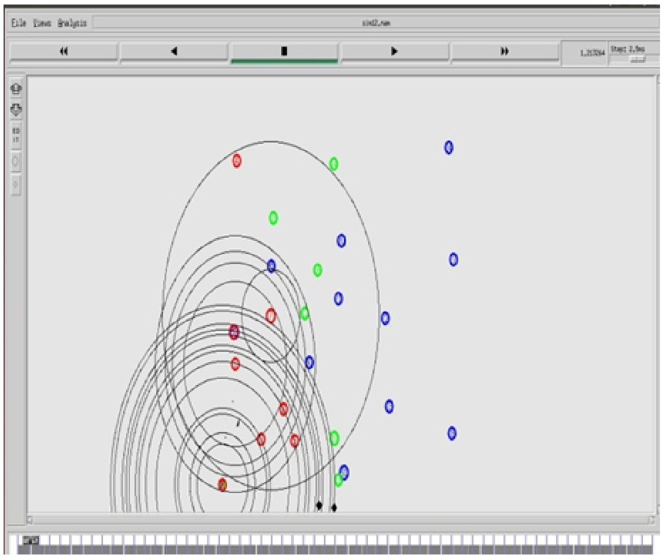

Fig.5. Broadcasting

REFERENCES

[1] M. Radi, B. Dezfouli, K. A. Bakar, and M. Lee, "Multipath routing in wireless sensor networks: Survey and research challenges," Sensors, vol. 12, no. 1, pp. 650–685, 2012.

[2] A. Ali, L. Latiff, R. Rahid, and N. Fisal, "Real time communication with power adaptation (rtpa) in wireless sensor network (wsn)," in Proc. of International Conference on Computing Informatics, June 2006.

[3] D. Baghyalakshmi, J. Ebenezer, and S. A. V. SatyaMurty, "Low latency and energy efficient routing protocols for wireless sensor networks," in Proc. of International Conf. on Wireless Communication and Sensor Computing, Jan 2010.

[4] M. Kadi and I. Alkhayat, "The effect of location errors on location based routing protocols in wireless sensor networks," Elsevier Egyptian Informat- ics Journal, no. 0, pp. 1 – 8, 2015.

[5] D. Pompili, T. Melodia, and I. F. Akyildiz, "Three-dimensional and two- dimensional deployment analysis for underwater acoustic sensor networks," Elsevier Ad Hoc Networks, vol. 7, no. 4, pp. 778 – 790, 2009.

[6] H. Aksu, D. Aksoy, and I. Korpeoglu, "A study of localization metrics: Evaluation of position errors in wireless sensor networks," Elsevier Com- puter Networks, vol. 55, no. 15, pp. 3562 – 3577, 2011.

[7] J. Al-Karaki and A. Kamal, "Routing techniques in wireless sensor net- works: a survey," IEEE Trans. Wireless Communications, vol. 11, no. 6, pp. 6–28, Dec 2004.

[8] H. de Oliveira, A. Boukerche, E. Freire Nakamura, and A. Loureiro, "An efficient directed localization recursion protocol for wireless sensor networks," IEEE Trans. Computers, vol. 58, no. 5, pp. 677–691, May 2009.

[9] A. Varga and R. Hornig, "An overview of the omnet++ simulation environ- ment," in Proc. of the 1st Intr. Conf. on Simulation Tools and Techniques for Communications Networks and Systems and Workshops, April 2008.

[10] A. E. Abdallah, T. Fevens, and J. Opatrny, "High delivery rate position- based routing algorithms for 3d ad hoc networks," Elsevier Computer Com- munications, vol. 31, no. 4, pp. 807–817, Mar. 2008.

[11] R. Zurawski, "Keynote: Wireless sensor network in industrial automation," in Proc. of International Conference on Embedded Software and Systems, May 2009.